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APPLICATION FOR UNITED STATES LETTERS PATENT

VACUUM PUMP WITH FAIL-SAFE VANES

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CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of U.S. patent application Serial No. 10/269,117 which was filed with the U.S. Patent and Trademark Office on October 11, 2002.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention generally relates to a vane pump and, more particularly, to a vacuum vane pump for use on aircraft to generate a vacuum condition necessary for the operation of aircraft instrumentation.

2. Description of the Related Art

[0003] Sensitive analog guidance instrumentation and indicator displays such as gauges used on small aircraft and principally relied upon by aircraft pilots in the operation of such aircraft require a suitable operating environment to properly function. Such instrumentation are highly susceptible to variations in their operating environment and, in particular, to changes in barometric or cabin pressure which will affect, among other things, altimeter measurements and, hence, the gauge displays of such measurements. For these reasons, it is imperative that such guidance equipment and indicators operate in as close to a vacuum condition as practicable so that they provide a true indication of aircraft operating parameters.

[0004] Vane pumps are commonly used to generate the necessary vacuum for small aircraft instrumentation. With reference to FIG. 1, known vane pumps 5 typically consist of a rotor 10 secured for rotation with a motor-driven shaft 12 by a key 13. The rotor 10 has a peripheral surface 14 and is surrounded by a casing or housing 30 having an inward facing surface 32. Rotor 10 is mounted eccentrically in housing 30 so that its peripheral surface 14 and the confronting inner surface 32 of housing 30 define a crescent-shaped chamber 34 therebetween. The rotor also has a plurality of radially-extending slots 16 defined and extending between an inner end 17 and an outer end 19 coterminous with peripheral surface 14. A plurality of fingers or vanes 20 (five of which are shown by way of illustrative example) are slidably engageable in slots 16. Each vane 20 has an inner end 21 disposed proximate end 17 of its corresponding slot, and an outer tip 22 which as the vane 20 is radially-outwardly displaced along its slot 16 by the centrifugal force exerted on the vanes through rotation of rotor 10, is driven beyond outer end 19 and into pressed abutment against the internal surface 32 of housing 30. As rotation of the rotor causes vane tips 22 to pressingly advance circumferentially about the inner surface 32 of housing 30, the air or gas in the crescent-shaped chamber 34 is alternately compressed and expanded to create a vacuum.

[0005] In order to extend the resulting vacuum to the appropriate instruments in, for example, an aircraft cockpit, porting of vacuum chamber 34 is effected, as is known in the art, for example in the manner shown in U.S. Patent No. 5,100,308 which also describes multiple stages and arrangements for changing the eccentricity of the rotor in the housing to enable regulation of the amount of vacuum or positive pressure

generated by the vane pump. The slots and vanes need not be oriented in a strictly radial manner but may, instead, be skewed as for example disclosed in FIGs. 6 and 7 of U.S. Patent No. 6,086,332.

[0006] The vanes 20 in a conventional vane pump of the type heretofore described and depicted in FIG. 1 are typically formed of carbon and the housing 30 is typically constructed of aluminum. During pump operation the vane tips 22 incur steady wear from friction as they press against and slidingly contact the inner housing surface 32 during rotation of rotor 10. Over time, the gradual wearing of the tips 22 causes shortening of the vanes relative to their respective slots 16, thus requiring that the vanes be displaced or travel farther radially outward along the slots; as a result, for each one the distance between inner slot end 17 and inner vane end 21 increases as the outer tip 22 continues to frictionally engage surface 32. Put another way, the length of each vane 20 that remains within its respective slot 16 as the vane tip 22 is centrifugally pressed against confronting housing wall surface 22 steadily decreases as the pump 5 is operated. Eventually, one or more of the vanes decrease in length to a point that its portion that extends out of its respective slot 16 approaches or exceeds in length the portion that remains within the slot. This condition commonly results in a sudden and catastrophic breaking or dislodging of one or more of the vanes from their respective slots in or about the widest part of chamber 34, causing an abrupt loss of vacuum. Often one broken vane initiates a catastrophic destruction of additional ones of vanes and, therefore, a complete loss of vacuum. Unexpected reduction or total loss of vacuum adversely affects instrumentation readings and can lead to erroneous decisions

in controlling the aircraft. Even with a vacuum loss warning system, the information displayed to a pilot on the gauges is unreliable at best.

[0007] The long-accepted solution, according to the prior art, is regular scheduled maintenance of vane pumps through periodic disassembly to detect the extent of vane wear, a time consuming and costly procedure that, without early replacement of pumps typically capable of safely operating for additional extended periods of time, is an unreliable predictor of imminent pump failure.

SUMMARY OF THE INVENTION

[0008] It is therefore an object of the invention to provide an improved vane pump in which the likelihood of unexpected broken vanes and the resulting catastrophic loss of a vacuum condition caused by the vane pump is reduced.

[0009] In accordance with the invention, a vane pump is provided for creating a vacuum condition in a pump chamber formed between a housing wall and a rotor. The rotor has a plurality of slots, each containing a vane slidably engageable within the respective slot. The vanes are radially outwardly displaced by centrifugal force as the rotor is operatively rotated in that the leading edges of the vanes are outwardly advanced from the respective slot mouths or openings into pressed contact with the housing wall. The vanes and slots are configured to capture within the slots a stop or obstruction carried on the radially inner end of each vane and thereby limit the radial displacement of the vanes beyond the slot openings or mouths. This construction thereby prevents or notably reduces the possibility of vane breakage within the chamber and, hence, prevents an abrupt catastrophic loss of vacuum.

[0010] In a preferred embodiment, the stop is created by forming a unitary flange on an engagement region of each vane, such as at or proximate an inner end of each vane, for engagement with a protrusion, shoulder or other obstruction positioned at a predetermined location relative to the slot opening. As the vanes erode or decrease in length through continued frictional contact with the housing wall, a gradual, rather than an abrupt, decrease or loss of vacuum pressure can be detected, indicating that immediate maintenance or servicing of the vane pump is required.

[0011] In another embodiment, a switch is activated to trigger an alarm or service indicator when a predetermined amount of wear has occurred on one or more of the pump vanes to signal that immediate pump maintenance is required.

[0012] Other objects and features of the present invention will become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits of the invention, for which reference should be made to the appended claims. It should be further understood that the drawings are not necessarily drawn to scale and that, unless otherwise indicated, they are merely intended to conceptually illustrate the structures and procedures described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like reference numerals indicate similar elements throughout the several views:

[0013] Figure 1 is a cross-section of a vane pump according to the prior art;

[0014] Figure 2 is a cross-section of a vacuum vane pump in accordance with a preferred embodiment of the present invention;

[0015] Figure 3 is a partial cross-section of a rotor in the pump of Figure 2, prior to significant wear of the vane tip;

[0016] Figure 4 is a partial cross-section of a rotor in the pump of Figure 2 when the vane tip is fully worn;

[0017] Figure 5 is a partial cross-section of a rotor in accordance with another embodiment of the present invention; and

[0018] Figure 6 is a partial cross-section of a rotor according to still another invention embodiment of the invention.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

[0019] A vacuum vane pump 50 constructed in accordance with the present invention is shown in FIG. 2. Like the prior art vane pump 5 of FIG. 1, pump 50 has a rotor 10 eccentrically aligned within a housing 30 and rotatable with respect thereto about a keyed shaft 12. The rotor has a plurality of slots 16 formed therein, with each slot occupied by a vane 20 dimensioned or profiled for sliding movement along a respective slot and partially outwardly therefrom through a slot opening or mouth 19. As explained above, as rotor 10 is rotated by shaft 12, the centrifugal force acting on the radially slidable vanes 20 displaces the vanes radially outward from shaft 12 so that the leading edges 22 of the vanes are driven beyond the slot openings 19 into pressed frictional abutment with the inner surface 32 of housing 30. The vanes act as wipers that force air along the eccentrically-shaped chamber 34 to create a vacuum condition.

[0020] Unlike the prior art pump of FIG. 1, the inventive pump 50 is configured with a safety feature effective to prevent over-extension of the vanes 20 into chamber 34. Without this safety feature, the vanes will continue to gradually wear away and shorten due to their frictional sliding engagement with inner housing wall 32 until the vanes either dislodge from the slots 16 or break off or facture within chamber 34. When a vane pump is used to provide critical operating vacuum to aircraft cockpit instrumentation and indicators, the sudden and complete loss of vacuum that typically results from vane dislodgement or breakage can lead to critical pilot error as the instrument indicators become disabled or unreliable.

[0021] In accordance with a preferred embodiment of the invention, the safety feature includes a reconfigured vane having a narrow elongated shaft portion 48 and an engagement region such as a head portion 46, which may, for example, be disposed at or proximate the radially innermost end of the vane 20 as shown in FIGs. 2-4. The slots 16 are configured to define a similarly narrow mouth or opening 19, as by forming a shoulder 44 in the slot walls, the opening 19 being dimensioned to allow sliding movement therethrough of shaft 48 but to obstruct and prevent passage of the wider head portion 46. In this manner, the vane head 46 serves as an anchor for vane-capturing abutment against slot shoulder 44. Thus, as the outer tips 22 of the vanes continue to gradually wear and erode through frictional contact against the inner surface 32 of the chamber during manual operation of the pump, the vanes are prevented from entirely exiting their slots and thereby initiating a catastrophic failure of the pump. Moreover, as the vanes wear down and are unable to become radially outwardly displaced beyond that permitted by the abstract of the head portion 46 and slot shoulder 44, a gap 50 will develop between the tips 22 and the chamber wall and result in a gradual reduction in the level of vacuum pressure. In this manner, a pilot of an aircraft in which the pump is operating will be alerted by the decreased vacuum that maintenance is required.

[0022] Other slot and vane configurations and modification can be employed and will be apparent to those having ordinary skill in the art for capturing the vanes and preventing them from completely exiting from their corresponding slots. Thus, the vanes 20 depicted in FIG. 2 to 4 can be implemented using a wide variety of shapes

whereby the vane head 46 is variously configured and positioned at different locations on or along the elongated vane. For example, the head 46 can be formed as a circumferential projection or ring that is located in predeterminately spaced relation from the radially inwardly-disposed end of the vane, rather than closely proximate or at that inward end as shown in FIGS. 2 to 4. Similarly, the contours and shaping of the projection or head 46 can take on any convenient form as a general matter of manufacturing efficiency and design choice. Thus, the vane head may by way of illustration be alternatively implemented as a selected plurality of laterally extending arms on the vane. In a similar manner, the implementation of the slot shoulder or the like for engagement with the vane head can be varied from that herein described, as for example by differently shaping or contouring or locating the slot shoulder or by defining the same as a separate element, such as a band or ring or the like, that is press-fit into or otherwise anchored to the slot for engagement with the vane head to capture the vane within the slot. The nature and extent of all such modifications are limited only by the requirement that the head 46 - of whatever form and/or location on or along the vane - be cooperatively engageable with a shoulder or other structure or wall shaping or contour that is defined along and/or as an integral or attached part of the vane slot so that the vane is captively prevented from fully exiting and thereby becoming entirely free and clear of the slot, and/or so that the vane cannot be outwardly displaced along the slot by centrifugal force beyond a predetermined point at which that longitudinal portion of the vane remaining within the slot is insufficient to maintain the radially-outwardly extending portion of the vane in the desired orientation in which its outer tip 22 is

disposed in confronting opposition to the housing wall surface 32. It is also within the contemplation of the invention that the vane slots be so defined in the rotor the vanes positioned therein are not radially aligned with the rotor shaft 12.

[0023] Another vane construction is shown by way of example in FIG. 5. There, a vane head 146 having a tapered sidewall 142 may be mounted within a rotor slot 116 having an opposingly defined wall 144 for mating engagement with the vane sidewall 142 as the vane erodes at its leading tip to captively prevent dislodgement of the vane from within the slot.

[0024] In still another embodiment of the invention shown in FIG. 6, a vane erosion indicator arrangement is implemented by positioning a contact switch 52 between the slot shoulder 144 and the vane head 146 so that, when the vane erodes to a predetermined extent, the head portion 46 engages and actuates switch 52 to operating an alerting signal, such as an indicator light, audible alarm, etc., in a known manner to inform a pilot or other user or operator that the pump is in need of maintenance or replacement. Although the switch is shown in FIG. 6 as mounted to the slot shoulder 144, it could alternatively be positioned elsewhere on the rotor or carried on the vane or in any other suitable location for actuation when the vane has become predeterminately worn.

[0025] Under ideal conditions, all of the vanes should experience through normal vane pump operation, substantially the same amount of erosion over time. Thus, a single switch 52 positioned for engagement with a selected one of the vanes may suffice to provide an appropriate vane pump erosion indicator. In reality, of course,

variations in material characteristics and numerous other factors cause the vanes to wear, as their tips frictionally slide along the opposed housing inner wall surface, at rates that are at least slightly or marginally different. Indeed, such variations from vane to vane in the rate of wear are both expected and desired to result in only a relatively small and gradual decrease in the vacuum generated by the vane pump as the captive vanes variously wear down to predetermined points at which their individual tips at first no longer sealingly press against, and then define a gap with, the housing inner wall surface. It is accordingly preferred that an indicator switch or the like is provided for activation by each of the vanes as its outward tip wears down to the predetermined extent, or alternatively that an other detection arrangement is employed to detect the predetermined threshold wear of each vane of the inventive vane pump.

[0026] While there have shown and described and pointed out fundamental novel features of the invention as applied to preferred embodiments thereof, it will be understood that various omissions and substitutions and changes in the form and details of the methods described and the systems and components and devices illustrated, and in their operation, may be made by those skilled in the art without departing from the spirit of the invention. For example, it is expressly intended that all combinations of those elements which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention. Moreover, it should be recognized that structures and/or elements shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or

embodiment as a general matter of design choice. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.